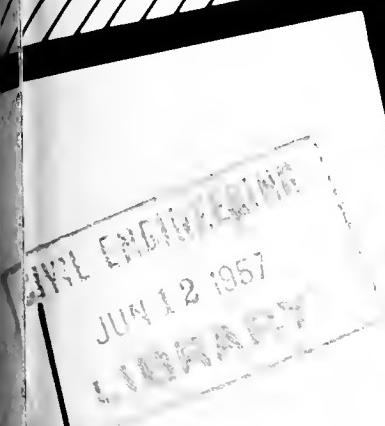


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HIGHWAY RESEARCH AND THE
EXPANDED HIGHWAY CONSTRUCTION
PROGRAM
JUNE, 1957
NO. 15

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by
K. B. WOODS

Joint
Highway
Research
Project

PURDUE UNIVERSITY
LAFAYETTE INDIANA



HIGHWAY RESEARCH AND THE EXPANDED HIGHWAY CONSTRUCTION PROGRAM

TO: K. B. Woods, Director
Joint Highway Research Project

June 12, 1957

FROM: H. L. Michael, Assistant Director

Filer: M. J.

Attached is a technical paper entitled, "Highway Research and the Expanded Highway Construction Program," by Professor K. B. Woods, Head of the School of Civil Engineering. This paper was presented at the Annual Meeting of the Division of Engineering and Industrial Research, National Research Council in Washington, D. C., on May 23, 1957.

This paper discusses the AASHO Test Road in Illinois and the accelerated highway program. The role of the Highway Research Board is also discussed and the impact of the highway construction program is briefly presented.

Respectfully submitted,

Harold L. Michael
Harold L. Michael, Secretary

HLMI:mgb

Attachment:

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	G. A. Hawkins	K. B. Woods
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TECHNICAL PAPER

HIGHWAY RESEARCH AND THE EXPANDED HIGHWAY CONSTRUCTION PROGRAM

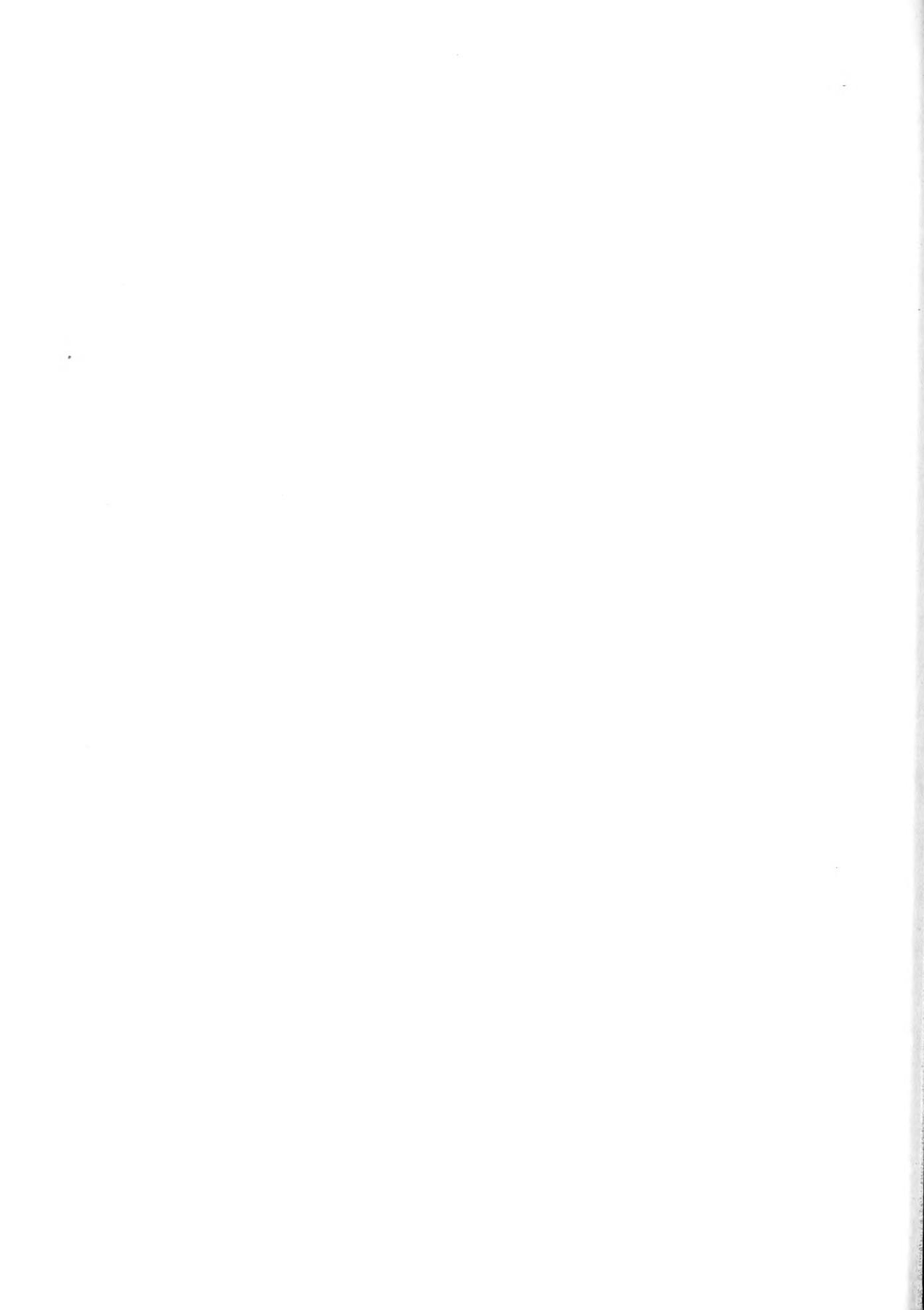
by

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Joint Highway Research Project
File: 14-5

Purdue University
Lafayette, Indiana

June 12, 1957



HIGHWAY RESEARCH AND THE EXPANDED HIGHWAY CONSTRUCTION PROGRAM

The United States in developing an adequate highway system within the next 15 years, at a cost of about \$100 billion, will draw heavily upon the economic resources of the nation. It is obvious that to plan, design, construct, operate, and maintain the vast highway system will require economical and efficient use of manpower, materials, machinery and equipment, and the development and utilization of new methods and techniques in all phases of highway development. It is also equally obvious that an effective program of research must be conducted to provide solutions to the many unsolved problems, to improve present solutions, and to facilitate development of the highway program.

Congress, in recognizing deficiencies in the highway construction program contributed significantly to financing the program. In addition, the Bureau of Public Roads was given a mandate by Congress to conduct research studies in areas where solutions to problems are urgently needed. The results of these studies are expected to greatly augment present information. Some will supplement those in progress by the Highway Research Board and other agencies concerned with the highway function.

The mandate by Congress and the execution of the several research studies by various agencies does not mean that research has not been conducted previously. In some areas this may be true, but in the main, it does suggest that objective answers through enlarged programs of research must be obtained quickly if the highway program is to develop satisfactorily.

Research in highway transportation is not of recent origin in the United States. The construction of the Cumberland Road (1), the development of

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activities within the Office of Road Inquiry and later within the Bureau of Public Roads, the Bates Road Test in Illinois (2), the investigations of the Coordinator of Transportation (3) and the Board of Investigation and Research (4), various studies by the several states and universities, and the recent work under the direction of the Highway Research Board represent programs of research in various areas of highway transportation. Each has contributed to the fund of knowledge.

The Highway Research Board through the several departments and committees has been actively engaged in promoting and conducting research in a great many areas. The development of the test road method of conducting highway research has received considerable attention of the Board in recent years. In general, these tests have been concerned with the economics of highway design and operation and may contribute significantly to how highway costs should be assigned equitably to the users and beneficiaries of highways.

It is the purpose of this paper to discuss very briefly the AASHO Road Test underway in Northern Illinois and the greatly accelerated highway construction program. The need for the Road Test and the relationship of the research findings to the new construction requires some consideration - likewise the role of the Highway Research Board of the National Research Council in these two enterprises is a subject of considerable significance. The full impact of the new program of construction and the finished roads themselves can only be estimated - yet this subject is of utmost importance to the entire nation.



Field Road Tests

The first such road test since World War II was located in Maryland and is known as Road Test One - MD (5). The results, published in 1952, have led to additional research and a much better understanding of the reasons for failures in pavements. The second project, located near Malad, Idaho, is known as the WASHO Road Test (6). The results were published in 1954.

The third field project, now in progress, is known as the AASHO Road Test (7). It is located between LaSalle and Ottawa, Illinois, about 80 miles southwest of Chicago. All three of these large field tests have been conducted by the Highway Research Board of the National Academy of Sciences, National Research Council in cooperation with the Bureau of Public Roads, many of the States, and interested industries.

The specific objectives of the AASHO Road Test are quoted here from a document entitled "Objectives of the AASHO Road Test" which was approved by the Advisory Committee at a scheduled meeting in LaSalle, Illinois, on May 1, 1951.

"General:

"In the rapidly changing highway construction field, more information is needed on how pavement structures and bridges of various engineering standards are affected by motor vehicles of different sizes, weights, and axle-loading characteristics. The AASHO Road Test will seek to make available data pertaining to this problem under a given set of conditions and for the weather prevailing at the site during the test.

"Special traffic lanes will be built on a fine-grained soil of known characteristics in an area of seasonal frost penetration. Each traffic lane will be made up of various thicknesses of base and subbase and various surface thicknesses of asphaltic concrete, plain Portland cement concrete, and reinforced Portland cement concrete.

"Vehicles using the traffic lanes will range from very light to very heavy types. They will be operated continuously during all seasons. Each lane will carry only a group of vehicles of one type. Special instruments will count the load applications and keep records of the behavior and conditions of the test sections. Similar studies will be made on bridges of various designs to be built into the test loops.



"Objectives:

"1. To determine the significant relationships between the number of repetitions of specified axleloads of different magnitude and arrangement and the performance of different thicknesses of uniformly designed and constructed asphaltic concrete, plain Portland cement concrete, and reinforced Portland cement concrete surfaces on different thicknesses of bases and subbases when on a basement soil of known characteristics.

"2. To determine the significant effects of specified vehicle axleloads and gross vehicle loads when applied at known frequency on bridges of known design and characteristics. The bridges will include steel I-beam design, conventional reinforced concrete design, and prestressed concrete design.

"3. To make special studies dealing with such subjects as paved shoulders, base types, pavement fatigue, tire size and pressures, and heavy military vehicles, and to correlate the findings of these special studies with the results of the basic research.

"4. To provide a record of the type and extent of effort and materials required to keep each of the test sections or portions thereof in a satisfactory condition until discontinued for test purposes.

"5. To develop instrumentation, test procedures, data, charts, graphs, and formulas, which will reflect the capabilities of the various test sections; and which will be helpful in future highway design, in the evaluation of the load-carrying capabilities of existing highways and in determining the most promising areas for further highway research."

In June 1956, Congress passed, and President Eisenhower signed, new highway legislation (8). Section 108 (k) of this law directed the Secretary of Commerce ". . . to take all action possible to expedite the conduct of a series of tests now planned or being conducted by the Highway Research Board of the National Academy of Sciences, in cooperation with the Bureau of Public Roads, the several States, and other persons and organizations, for the purpose of determining the maximum desirable dimensions and weights for vehicles operated on the Federal-Aid highway systems, including the Interstate System, and, after the conclusion of such tests, but not later than March 1, 1959, to make recommendations to the Congress with respect to such maximum desirable dimensions and weights."

This most recent test road contains four basic loops including dual tangents of 6600 feet with a turn around at each end. In addition, two



smaller test loops are being constructed which will not be subjected to test traffic. All of the test sections are scheduled for completion of construction in 1957. Rigid and flexible pavements of controlled cross-section design are being placed on bases and subbases of specified depth. These pavements will be subjected to controlled traffic. Extreme care in locating the test sections in an area of uniform soils, supplemented by good construction practices and control techniques, has made possible the building of uniform embankments and subgrades for the placing of bases and subbases. The test pavements will undergo axle loadings ranging from 2,000 to 30,000 pounds for the single axle and from 24,000 to 48,000 pounds for the tandem combination for sixteen hours a day, 6 days a week for two years.

Table I presents a summary of the design and testing features of this project estimated to cost \$19,200,000.

The project is located in an area which is reasonably representative of the soils and climatic conditions of the midwest, the northern tier of States of the United States and some parts of southern Canada. Correlation tests and interpolation will be required to use the research data for design purposes in the warmer, sandy-soil areas of the Gulf and Eastern Coastal Plains, for many sections of the arid and semi-arid regions of the west, and for the well-drained soil areas of New England.

In summary, the AASHO Road Test is not an ordinary test. The design of the experiments has been done with the best engineering and statistical design procedures available. The research data are to be collected through elaborate instrumentation being developed by a competent staff with the cooperation and advice of highly skilled instrumentation specialists. Measurements have been or will be made for control of construction, of the relationships between the behavior of the various pavement and bridge designs



TABLE I

Test axle loadings*	Loop A	Loop D	Loop C	Loop E	Loop F	Loop B
	12,000-lb. single 24,000-lb. tandem	30,300-lb. single 48,000-lb. tandem	22,400-lb. single 40,000-lb. tandem	2,000-lb. single 6,000-lb. single	No traffic Strain test traffic	18,000-lb. single 32,000-lb. tandem
Rigid Pavement:						
No. of test sections	68	68	68	40	56	68
Concrete slab thicknesses, inches	3.5, 5.0 6.5, 8.0	8.0, 9.5 11.0, 12.5	6.5, 8.0 9.5, 11.0	2.5, 3.5 5.0	2.5, 5.0, 9.5, 12.5	5.0, 6.5, 8.0, 9.5
Subbase thicknesses, inches	0, 3, 6, 9	0, 3, 6, 9	0, 3, 6, 9	0, 6	0, 3, 6, 9	
Flexible Pavements:						
No. of test sections	84	84	84	64	64	84
Asphalt Concrete Surfacing thicknesses, inches	2, 3, 4	4, 5, 6	3, 4, 5	0*, 1, 2, 3	1, 3, 5	3, 4, 5
Base thicknesses, inches	0, 3, 6	3, 6, 9	3, 6, 9	0, 3, 6	0, 6	0, 3, 6
Subbase thicknesses, inches	0, 4, 8	8, 12, 16	4, 8, 12	0, 4	0, 8, 16	4, 8, 12

Note: Special sections to study effects of paved shoulders, base types, etc., are not shown here.

*Surface treatment



and the various loadings, and of those phenomena that will help explain how pavement and bridge failures develop. Because voluminous data will be accumulated throughout this project, only data that will best serve a specific purpose are being taken and the most modern techniques in data accumulation and data reduction will be used. Wherever appropriate, high-speed electronic digital computers will be used for analysis. The final results are expected to provide much valuable information for use in the development of a more efficient and economical road network in the United States.

Some Research Aspects of the New National Road Program

The Federal Aid Highway Act of 1956 is another factor - a very major one - in the promotion of the development of a more efficient and economical road system. The huge 13-15 year program for a 41,000 mile national system of Interstate and Defense Highways linking 209 cities of 50,000 population or more was authorized by the Act. Additional money was also appropriated for the other Federal Aid systems as well as National Park and Indian reservation roads.

Along with the authorization of the expenditure of funds, Congress delegated responsibility to the Bureau of Public Roads for administering the program under the direction of a newly appointed Federal Highway Administrator. The States, however, will prepare the plans and let the contracts for the actual construction in cooperation with the Bureau of Public Roads. Congress included in this delegation of responsibility to the Bureau of Public Roads a mandate covering the investigation of five specified problem areas. These studies to be conducted by the Bureau of Public Roads require much research. Collateral research by affiliates of the Highway Research Board and other agencies are essential to the successful completion of these mandated studies within the time limits set by Congress.



The areas to be investigated and the dates the reports must be submitted to Congress (9) are as follows:

Due January 1958 - A more accurate estimate of the cost of completing the Interstate System. This will determine apportionments to states for 1960-1962. New estimates are required at intervals through 1968.

Due January 1958 - A study to aid Congress in establishing policy for the reimbursement of States for highways constructed in the period 1947-57 and included in the Interstate System. This is to include toll roads and free roads, if constructed to the approved standards.

Due March 1959 - An incremental cost study to determine the cost of building roads to meet demands of various classes and types of users. This will assist Congress in making an equitable distribution of taxes among various classes of vehicles using the federal aid highways or otherwise deriving benefits from them.

Due March 1959 - A study to determine the maximum desirable sizes and weights of vehicles.

Due March 1959 - A study to determine what the Federal Government can do to increase highway safety with emphasis on finding the causes of accidents and their bearing on road construction.

Impact of the New National Road Program

The impact of the new National Road Program - especially the Interstate System - on the economy and development of this nation will be far-reaching - these can only be estimated at present.

The growth and development of urban areas will be greatly affected by the new Interstate System. Over half of the Interstate funds will be spent for radial and circumferential routes in metropolitan areas. These new routes



will influence the growth pattern in these areas and will make suburban living even more attractive.

Interstate routes will also stimulate the growth of new industrial and living areas between metropolitan areas. Although the New York Thruway has not been open to traffic very long, it is conservatively estimated that more than \$150 million have been expended on the construction of new industrial plants along the route. Perhaps, because of overlapping metropolitan areas, we may eventually have a continuous city between Washington and Boston. Other such continuous sections may also develop extending from such centers as Chicago and Detroit, Los Angeles and San Diego (10).

This rapid growth will create problems which need study. Changing patterns of living will result in urban areas oriented to highways instead of rivers and harbors as in the past. Where will the new areas obtain water and suitable facilities for disposal of wastes? Will these new areas be properly planned with parks, schools, shopping centers, industrial developments, cultural facilities and all the other things that make a community a good place to live? Will public transit be abandoned or will public transit operation become a shuttle service from outlying parking areas to the downtown central business district? Will the growth of urban areas along highways in fertile farm land areas seriously deplete our supply of agricultural land? Since subdivisions finger out alongside our major highways perhaps consideration should be given to the use of the less productive lands for location of the highway and subsequent construction of factories, shopping centers, and the homes themselves and reservation of the more fertile lands for agricultural purposes. As one good farm after another is subdivided, adjacent farms face the same prospect. The value of the farm land increases along with real estate taxes, to the extent that agricultural pursuits can

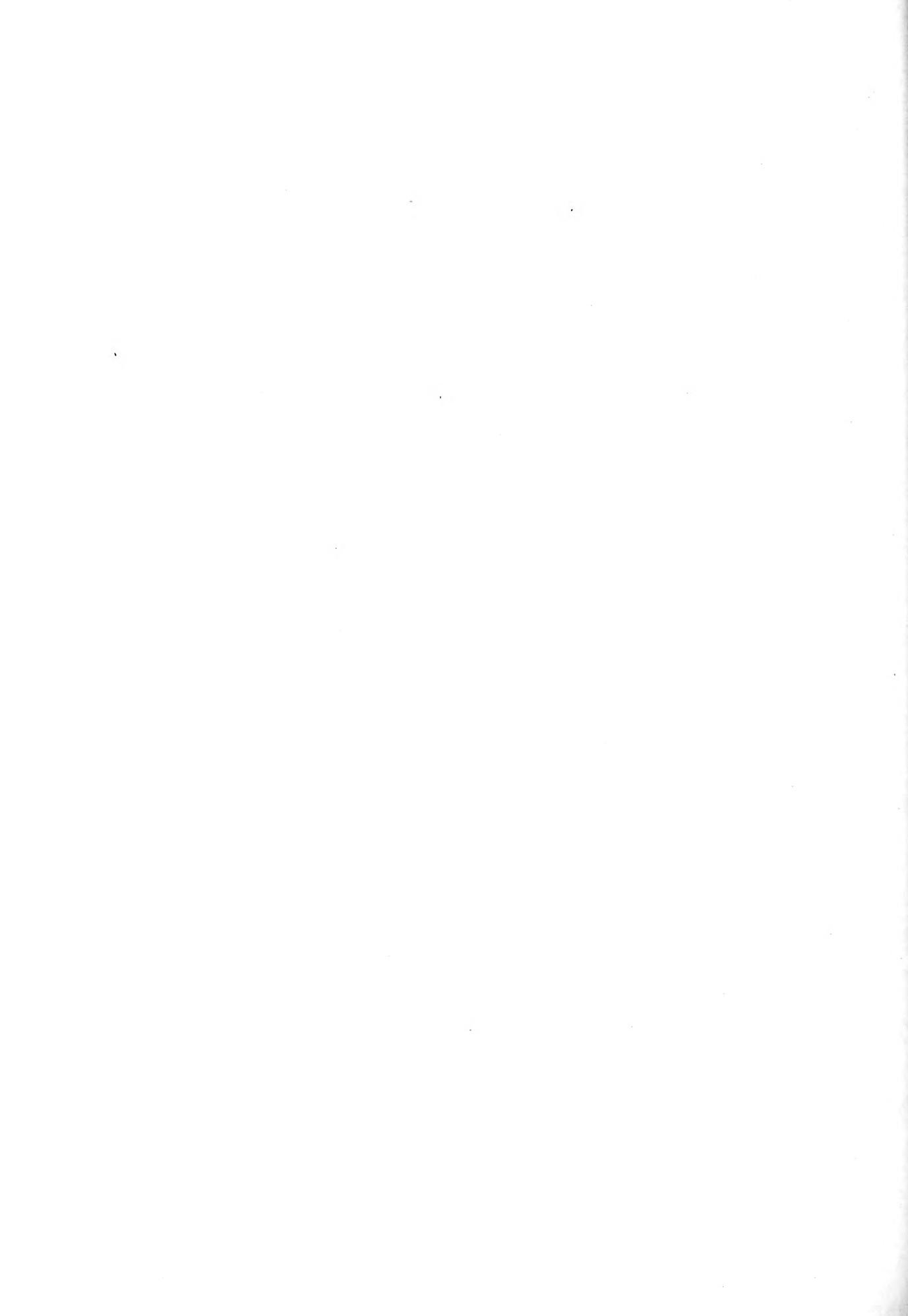


no longer be profitable. Items of this character need immediate research attention. In this respect Suggitt (11) states "During the past 15 years, 17 million acres, or about 5 percent of the nation's total crop land, has been converted to other uses. Of this total, about three-fifths has gone into private non-farm developments, and the other two-fifths into non-farm uses." This trend will continue as the new highway facilities come into use - especially so with the increase in the trend to decentralize industry, use one-story buildings, and move people from heavily populated centers to more spacious rural areas near modern roads. An expressway encourages commuting.

All highways of the United States will occupy 17 million acres of land (nearly 1/10 acre per capita) including about one and one-half million acres for the 41,000 miles of new Interstate Highway System to be completed by 1970. This amounts to over 2,000 square miles of land (the entire State of Rhode Island has 1,214 square miles of surface). Since this new system is mostly limited access and on new right-of-way, much new land will be required to build the new system.

One of the outstanding legal and political problems resulting from the new highway program is that of advance acquisition of right-of-way (12). The public must be informed as to the reasons for the location of the Interstate Highway System as it is being designed. They should be aware of the reason for and philosophy of the limited access except. At the same time it is important that land costs be kept in hand so that the entire program will not be vitiated. Many states lack proper legislation for advance land acquisition (13).

One of the great unknowns in the new highway program is the future status of mass transportation (14). The current trend is decreased use of mass



transit by the public could well be accentuated by the new highway program - yet proper planning of the highway systems in and about the larger cities could facilitate the use of express buses and thereby aid commuting in the large cities, and reduce the need for off-street parking in the downtown areas.

There are no foreseeable major changes to be made in the over-all road design concept, except those which may result from research findings of the AASHO Test Road. On the other hand, the new road system will stimulate more research in geometric design and operation, new interchange designs, and frontage road treatments. The use of radar for vehicle control and traffic surveillance, new concepts of illumination for night driving, new methods for snow and ice removal, and electronic controls for operating metropolitan freeway systems may well be in use in the years ahead. Certainly, safety to the motorist will be uppermost in the minds of the designers and every effort will be made to produce a road which is interesting, safe and efficient for the American motorist.

The immediate economic impact on the nation will be far-reaching. Reese (15) states that "it took the Romans 500 years to build the 50,000 miles of their famous single-lane highway system . . ." It is expected that the 41,000 miles of Interstate system will be built in about 15 years. The program will be of great economic significance to industries other than road constructors and to our resources. The Bureau of Public Roads has estimated that 49 million tons of steel, 1,339 million barrels of cement, 128 million tons of bituminous material, 9,710^{million} tons of aggregate, and large quantities of other construction materials will be needed in the highway construction program (16). Most of the material will be needed for the Interstate System.



Manpower is also needed. One of the most critical problems of the new program is that of a shortage of civil engineers. This shortage is already being reflected in college enrollment in Civil Engineering and in salaries for civil engineers. Civil Engineering enrollment is increasing steadily each year, but it is not increasing as rapidly as the enrollment in Electrical Engineering, Mechanical Engineering and Aeronautical Engineering. At Purdue University acceptance salaries for men with B.S.C.E. degrees has risen in the past 15 months from about \$400 a month to \$500 a month for June 1957 graduates. Many men have offers much above this figure with some offers above \$7,500 per year. The competition for civil engineers is beginning to cause the States to increase salaries of the engineers. Ohio, for example, now pays its top administrator \$30,000 per year (17).

Immediate steps must be taken to establish good personnel practices, effective salary scales, optimum use of technicians, and a basic concept of "no political interference" in the development of engineering organizations which must be geared to a completely professional attitude. If these changes do not take place the country is faced with a road design and construction program which could be poorly executed because of a shortage of competent civil engineers.

Highway Research Board

There can be no question about the impact of the new highway program in stimulating research. Increased interest is apparent in the fields of materials, traffic, finance, highway laws, urbanization and planning, and in road design itself as indicated by the AASHO Test Road. Automobile manufacturers, too, are feeling the impact of the new modern highway. There is an indication of a closer relationship between the road designer and the automotive engineer. It is entirely possible that a new concept of a road-car combination will be evolved before the entire program is completed.

The far-reaching results of the Highway Research Board's efforts in the highway research field are well demonstrated in the conduct of the three road tests - and especially so in connection with the current project described earlier in this paper. However, the work of the Board is much broader than is indicated by the field test projects alone. Work in such fields as traffic and operations, urban planning, economics, finance and administration is expanding rapidly but not at the expense of the work in the well-established fields - soils, materials, maintenance, and design.

The stated functions of the Board are (18): "To provide a comprehensive national program for highway research, to assist existing organizations to coordinate their activities therein, and to serve as a clearing house for information on completed and current research."

The Board continues to fulfill these obligations by stimulating research through the several departments and project committees; by conducting the annual meeting; by publication of proceedings, bulletins, highway abstracts, and special publications; and by the use of the correlation service.

In January 1957, the writer summarized his views concerning the Highway Research Board and the new construction program as follows (19):

As to the future, there can be no question of the importance of the greatly accelerated highway construction program to highway research, and of the seriousness of the impact of this program on the Highway Research Board. Of equal significance to highway research, however, will be the design, construction, and operation of the highway systems of the country.

The reports on the greatly expanded work of the Board during the past few years and the quality of the program of the annual meeting, January 1957, are certain signs that the challenge is being met. The Executive Committee has provided for expansion in membership and the reorganization of the basic



structure of the Committee to provide for greater effectiveness on the part of the Board for meeting the basic issues in the days and years immediately ahead.

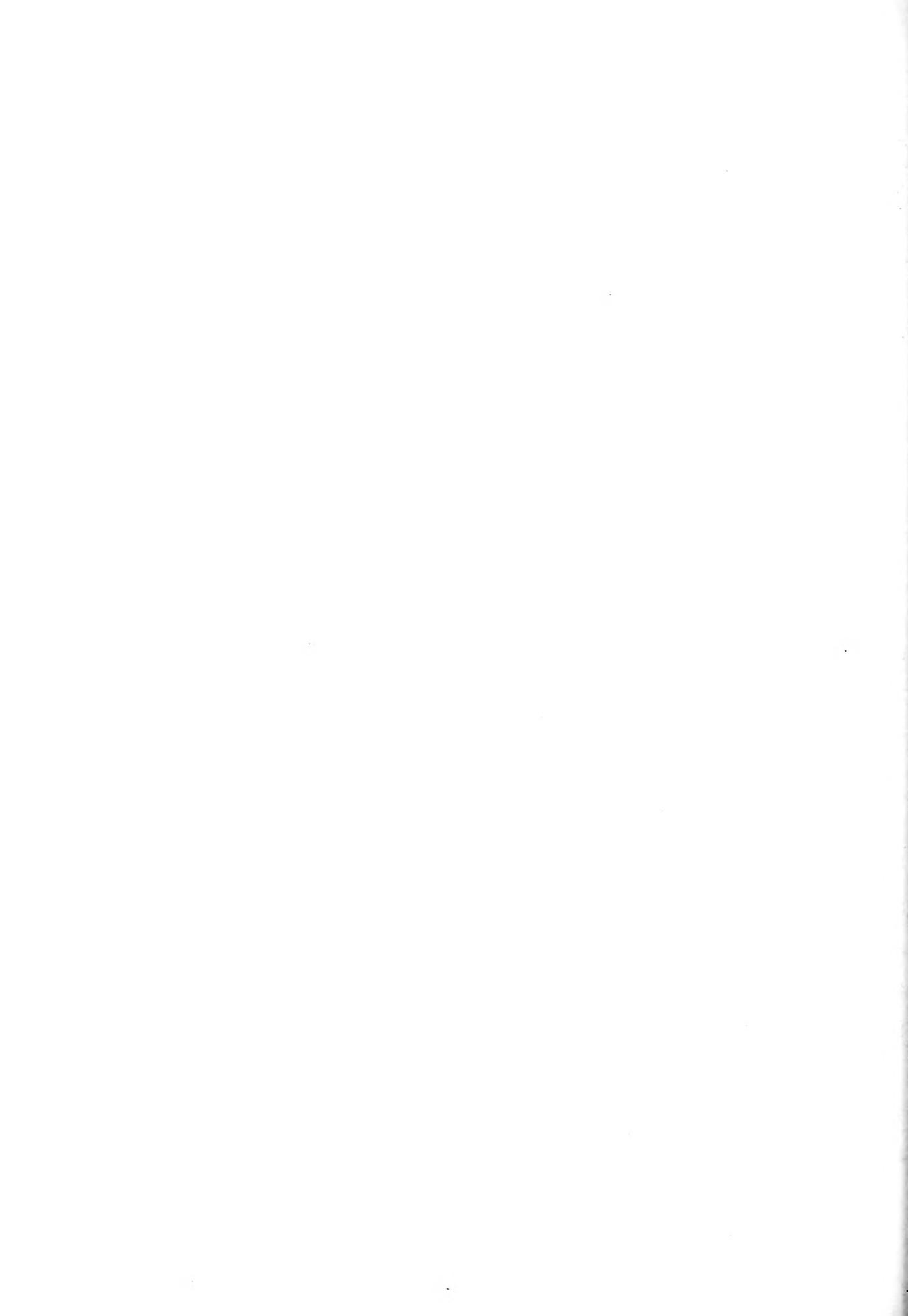
There will be a tendency in some agencies to divert engineers from research to producing plans for the expanded program because of the shortage of personnel. Such diversion should be kept to a minimum, and positive steps should be taken at the national level to insure funds and personnel for the needed expansion of research activity.

The short-term studies being made for the use of Congress in connection with the Federal Aid Act and the AASHO Road Test can form the basis for planning additional research efforts for the 1960 decade;

Universities should not be overlooked in planning expanded research programs. Already, there are indications that more men are returning for graduate work in highway engineering. If more funds can be provided for research assistantships for these men, overall research programs can be expanded. Possibly a planned program of grants-in-aid should be developed to expedite research on projects related to the expanded highway program.

It is this writer's opinion that the six departments of the Board, Economics, Finance and Administration; Design; Materials and Construction; Maintenance; Traffic and Operations; and Soils, Geology, and Foundations, and the 66 technical committees will expand their activities greatly with the prospect that new committees and perhaps new departments will be needed before the new highway program is completed.

Furthermore, the total impact of this new program is of such an order of magnitude that this body should now give careful consideration toward establishing a task force committee to investigate the impact of the expanded



highway program on other forms of transportation - water, rail, air and pipeline, as well as the impact on agriculture, land use, conservation of water, development of recreational facilities, sanitation, and the entire field of urban planning should be studied.

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